Estimation of Genetic Parameters for Growth and Body Measurement Traits in Different Ages in Iranian Makuei Sheep

Research Article

S. Varkoohi[1*], H. Bani-Saadat[1] and S. Razzagh-Zadeh[2]

[1] Department of Animal Science, Faculty of Agriculture, Razi University, Kermanshah, Iran
[2] Animal Science Research Institute, West Azarbayjan, Urmia, Iran

*Correspondence E-mail: s.varkoohi@razi.ac.ir
Online version is available on: www.ijas.ir

ABSTRACT

The present study aimed to estimate heritability, genetic and phenotypic correlations between body weight and body measurement traits in Iranian Makuei sheep. The used data were collected from 1989 to 2012 at Makuei Sheep Breeding Station in Maku (West Azarbayjan province). The data included body weight and five body measurement traits (body length (BL), heart girth (HG), withers height (WH), rump height (RH) and leg circumference (LC)) in 6, 12 and 18 months of age with 400, 900 and 350 records in different time, respectively. The data were analyzed using multi-trait animal model through DFREML software. Results showed that the estimated heritabilities for body weight and body measurement traits in 12 months of age is less than those for 6 and 18 months of age; those comes down from 6 to 12 months of age, then go up to 18 months of age. In six months of age the highest and lowest genetic correlations were between body weight (BW) with WH and LC; respectively, and the highest and lowest phenotypic correlations were between BW with RH and LC; respectively. Genetic and phenotypic correlations between body weight in six months of age and body measurement traits were approximately high but with leg circumference were low. Genetic correlations in 12 months of age were generally higher than phenotypic correlations. Genetic correlations between body weight in 18 months of age and body measurement traits were moderate to high and the highest genetic correlation was found between body weight in 18 months of age and body length. The positive correlation between body weight and body measurements in different ages indicated that selection for body measurements would results body weight improvement.

KEY WORDS genetic correlation, heritability, sheep breeding programs.

INTRODUCTION

Makuie sheep breed is the dominate sheep breed in West Azarbaijan province (Iran) with a population size around 2.7 millions. This breed that is well adapted to cold and highland environments (Safari, 1986), is reared for meat as the main, and wool and milk as the secondary purposes. In order to design an effective selection programs to increase efficiency of sheep production, knowledge of genetic parameters of economical important traits is need (Brown *et al.* 1973).

Genetic and non-genetic factors have a highly impact on meat yield as a complex polygenic trait (Salako, 2006). To improve meat yield, biometric characters or measurement traits with simple genetic controls have been used as an indirect criterion in many domestic animal species (Salako, 2006). Using measurement criteria, breeders can be able to identify early maturing and late maturing animals with different sizes (Brown *et al.* 1973). Identifying appropriate animals in earlier growth stage will be worthful for selection and prediction of mature ranking. Body measurement traits and indices not only help breeders to evaluate animal

weight but also could be used as functional indicators in animal production (Salako, 2006).

It is important to determine the relationship among two or more measured characters at early time or at later time, since early selection is one of the modern selection programs apply for higher production in animals (Salako, 2006); also it is important to determine the relationship between body measurement traits at different ages group, as early selection is one of the main methods in animal breeding. Simple correlation analysis is usually preferred by researchers to determine degree and direction of relationship among body measurement traits (Cankaya and Kayaalp, 2007). Janssens and Vandepitte (2004) reported moderate to high heritability for three breeds of adult Belgian sheep. Their estimates of heritability for BL, HG and WH were 0.30, 0.45 and 0.43 in Blue du Main, 0.35, 0.39 and 0.57 in Suffolk, and 0.28, 0.40 and 0.40 in Texel.

Abbasi and Ghafouri (2011) reported that heritability estimates for BW, BL, HG, HW, HB and SC in Makuei sheep were 0.22, 0.11, 0.21, 0.17, 0.17 and 0.32, respectively. These estimates indicate that selection in Makuei sheep would generate moderate genetic progress in body weight and body measurements. Supakorn *et al.* (2012) reported that heritability estimate for BW, HG and BL were 0.32, 0.52 and 0.54 in sheep population in Thailand. Hamayun Khan *et al.* (2006) reported a high and significant correlation among height at withers and heart girth and body weight at 4 to 18 months age, and suggested that any of these variables or their combination would provided a good estimate for predicting body weight at early age of Beetal goats.

Mukherjee *et al.* (1986) and Singh *et al.* (1987) found that, there is high and significant correlation between body weight and chest girth in brown Bengal does and grey Bengal goats, respectively. Ravimurugan *et al.* (2013) showed that body weight and the body measurements were significantly correlated with each other in Kilakarsal sheep and body weight had higher association with chest girth than body length or height rump. Information of growth and body measurement recorded at Makuei Sheep Breeding Station provides an opportunity to estimate of genetic parameters and development of appropriate selection index. The aim of present study was to estimate heritability for body weight and body measurement traits at different ages (6, 12 and 18 months age); and genetic and phenotypic correlation between these traits.

MATERIALS AND METHODS

Data structure
The used data were collected from 1989 to 2012 at Makuei Sheep Breeding Station in Maku (West Azarbaijan).

The data included body weight and five body measurement traits (body length, heart girth, withers height, rump height and leg circumference) in 6, 12 and 18 months of age with 400, 900 and 350 records in different times, respectively. The investigated traits were withers height (WH), rump height (RH), body length (BL), heart girth (HG), leg circumference (LC) and body weight (BW). WH was defined as the distance from the surface of a platform on which the animal stands to the withers. RH was defined as the distance from the surface of a platform to the rump. BL refers to distance between first cervical vertebrae to the base of the tale where it joint the body. HG is a circumferential measure taken around the chest just behind the front legs and withers. The midpoint between hock and pin bone at right rear leg is used to measuring the circumference of rear legs (LC). For HG and LC the measuring tool was tape measure.

Statistical analyses
Preliminary data of body weight and body measurement traits were analyzed using generalized linear models (GLM) procedure of SAS to identify non-genetic factors affecting the investigated traits (SAS, 2011). The model for whole traits (body weight and body measurements) were included effects of lambing year, lambing month (January, February, March and April), sex (male and female), birth type (single and twin) and age of dam at lambing (2-7 years old). For whole traits, all the factors were significant (P<0.01), but for BW, BL, HB and LC, age of dam was not significant (p>0.05) in six month age and not significant (P>0.01) for all traits at 12 and 18 month of age, therefore were omitted from final model. Preliminary analyses (not shown) showed that influence of maternal effects can be was negligible and non-significant in six month age (P>0.05) and in 12 and 18 month age (P>0.01) for all variables. As a consequence, maternal effects were not included in the fitted model.

A six-trait animal model combined with REML procedure, which allowed for design matrices observations, was used to estimate variance components, heritability coefficients and correlations among those six traits, simultaneously. DFREML software package Meyer were used for analyzing the data using following model (Meyer, 2000):

$$y = X\beta + Za + e$$

Where:
y: vector of observations.
β: vector of fixed effects.
a: vector of random effects.
e: vector of random residual effects.
X and Z: incidence matrices relating observations to fixed and random effects, respectively.

It is assumed that additive genetic effects and residual effects are normally distributed with mean zero and variance A and I_e, respectively:

Where:

A: additive numerator relationship matrix obtained from pedigree structure.

I_e: identity matrix with orders of N (number of records).

σ_a^2 and I_e σ_e^2: additive genetic variance and residual variance, respectively.

RESULTS AND DISCUSSION

Descriptive statistics for different traits have been summarized at Table 1. The mean of BW, WH, RH, BL, HG and LC in Makuie sheep were measured in three ages group as 6, 12 and 18 months of age; data value were 27.08 ± 0.19, 56.73 ± 0.14, 58.80 ± 0.16, 42.87 ± 0.12, 70.41 ± 0.18 and 29.21 ± 0.12 for 6 months; 34.05 ± 0.19, 63.47 ± 0.13, 64.91 ± 0.14, 51.88 ± 0.15, 81.50 ± 0.19 and 33.08 ± 0.10 for 12 months; and 43.35 ± 0.27, 66.04 ± 0.17, 67.17 ± 0.17, 57.18 ± 0.19, 91.27 ± 0.23 and 36.13 ± 0.11 for 18 months of age, respectively. According to estimated values of coefficient of variation (CV %), BW was the most variable traits in three ages group. The reason of greater CV for BW was probably due to more variability in relation to the mean of body weight and effect of outside environment on this trait. Similar to this result, Janssens and Vandepitte (2004) found greater CV for body weight compared to body measurement traits in three breeds of Belgian sheep: Blue du Maine, Suffolk and Texel.

Studied traits in six months of age

Estimation of variance components and heritability for studied traits are shown in Table 2. The estimated heritabilities estimates were 0.49 ± 0.17, 0.46 ± 0.09, 0.48 ± 0.11, 0.45 ± 0.08, 0.47 ± 0.15 and 0.5 ± 0.19 for BW_6, WH_6, RH_6, BL_6, HG_6 and LC_6, respectively. The estimated Heritability for BW_6 was in agreement with report of Miraei-Ashtiani *et al.* (2007) in Sangsari breed (0.49). The estimated heritability for BW_6 in Iranian sheep ranged from 0.13 in Zandi breed (Mohammadi *et al.* 2011) to 0.49 in Sangsari breed (Miraei-Ashtiani *et al.* 2007).

Phenotypic and genetic correlations in six months of age are presented in Table 3. Results showed that phenotypic and genetic correlations ranged from 0.11 to 0.88 and 0.1 to 0.87, respectively. The maximum and minimum genetic correlations were between BW_6 with WH_6 (0.53) and BW_6 with LC_6 (0.17), respectively. Maximum and minimum phenotypic correlations were between BW_6 with RH_6 (0.57) and BW_6 with LC_6 (0.18), respectively.

Phenotypic and genetic correlations between RH_6 with BL_6 and HG_6 were medium and with LC_6 were very low. Phenotypic and genetic correlations between HG_6 and other traits were medium but with LC_6 were lower and LC_6 had relatively lower correlation with other traits; so the highest genetic and phenotypic correlations were between RH_6 and WH_6 (0.87 and 0.88, respectively); also the lowest genetic and phenotypic correlations were between RH_6 and LC_6 (0.10 and 0.11, respectively) in six months age. Sahin *et al.* (2011) reported the moderate and significant correlation value between BW_6 and HG (0.56) in Merino lambs. Rare researches have been published about estimation of genetic parameters at six months age in sheep; therefore it's hard to compare the results with others.

Studied traits in 12 months of age

Estimation of variance components and heritability coefficients for studied traits in 12 months of age are shown in Table 4. Heritability estimates were 0.34 ± 0.05, 0.23 ± 0.05, 0.25 ± 0.04, 0.20 ± 0.04, 0.29 ± 0.06 and 0.07 ± 0.04 for BW_{12}, WH_{12}, RH_{12}, BL_{12}, HG_{12} and LC_{12}, respectively. The estimated value of heritability for BW_{12} (0.34) was lower than those have been reported by Snyman *et al.* (1995) in Afrino breed (0.58) and by Bathaei and Leroy (1998) in Mehraban breed (0.44). On the other hand, our estimation is higher than those results have been reported by Bahreini-Behzadi *et al.* (2007) in Kermani breed (0.14) and by Miraei-Ashtiani *et al.* (2007) in Sangsari breed (0.10). Heritability estimates for BL, HG and WH are lower than results of Janssens and Vandepitte (2004) for three breeds of adult Belgian sheep.

In current study, heritability estimates at 12 months age were lower than six months age; it could be because of poor nutrition and low quality of pasture on sheep breeding station which can cause a big environmental variance.

Phenotypic and genetic correlations at 12 months of age are reported in Table 5. Results showed that genetic correlations were generally higher than phenotypic correlations. The estimated genetic correlations ranged from 0.35 to 0.99, while corresponding values for phenotypic correlations were ranged from 0.28 to 0.92. These results were in agreement with reports for Belgian blue du Maine, Suffolk, Texel sheep (Janssens and Vandepitte, 2004).

Genetic and phenotypic correlations between BW_{12} and body measurement traits were very high and moderate, respectively. The highest genetic and phenotypic correlation were between HG_{12} and BW_{12} (0.95 and 0.63). The high and significant correlations between BW_{12} with HG and RH show these two traits or their combination can be good estimation for live body weight in 12 months age in Makuie sheep.

Table 1 Descriptive statistics for body weight at year of age (BW), withers height (WH), rump height (RH), body length (BL), heart girth (HG) and leg circumference (LC) for different traits

Item	Traits					
	BW	WH	RH	BL	HG	LC
6 month						
No. of records	400	400	400	400	400	400
No. of sire	12	12	12	12	12	12
No. of dam	24	24	24	24	24	24
Mean	27.08 (kg)	56.73 (cm)	58.80 (cm)	42.87 (cm)	70.41 (cm)	29.21 (cm)
SE	0.19	0.14	0.16	0.12	0.18	0.12
CV (%)	14.32	4.97	5.43	5.88	5.30	8.18
12 month						
No. of records	900	900	900	900	900	900
No. of sire	102	102	102	102	102	102
No. of dam	593	593	593	593	593	593
Mean	34.05 (kg)	63.47 (cm)	64.91 (cm)	51.88 (cm)	81.50 (cm)	33.08 (cm)
SE	0.19	0.13	0.14	0.15	0.19	0.10
CV (%)	17.44	6.44	6.43	9.07	7.04	8.51
18 month						
No. of records	350	350	350	350	350	350
No. of sire	10	10	10	10	10	10
No. of dam	21	21	21	21	21	21
Mean	43.35 (kg)	66.04 (cm)	67.17 (cm)	57.18 (cm)	91.27 (cm)	36.13 (cm)
SE	0.27	0.17	0.17	0.19	0.23	0.11
CV (%)	12.05	4.99	4.77	7.13	4.82	6.31

SE: standard error.
CV: coefficient of variation.

Table 2 Variance components for body weight (BW_6), withers height (WH_6), rump height (RH_6), body length (BL_6), heart girth (HG_6) and leg circumference (LC_6) in six months age

Traits	BW_6	WH_6	RH_6	BL_6	HG_6	LC_6
σ_a^2	5.65	2.85	3.71	2.16	6.35	2.72
σ_e^2	5.81	3.35	3.78	2.64	7.18	2.75
σ_p^2	11.46	6.20	7.50	4.80	13.53	5.47
$h^2 \pm SE$	0.49±0.17	0.46±0.09	0.48±0.11	0.45±0.08	0.47±0.15	0.5±0.19

σ_a^2: additive genetic variance; σ_e^2: residual variance; σ_p^2: phenotypic variance and $h^2 \pm SE$: heritability estimates and standard error.

Table 3 Phenotypic and genetic correlations among body weight (BW_6) with withers height (WH_6), rump height (RH_6), body length (BL_6), heart girth (HG_6) and leg circumference (LC_6) in six months age

Traits	BW_6	WH_6	RH_6	BL_6	HG_6	LC_6
BW_6	-	0.54	0.57	0.50	0.52	0.18
WH_6	0.53	-	0.88	0.43	0.52	0.30
RH_6	0.57	0.87	-	0.39	0.42	0.11
BL_6	0.49	0.42	0.38	-	0.45	0.26
HG_6	0.50	0.51	0.41	0.44	-	0.29
LC_6	0.17	0.16	0.10	0.26	0.28	-

Studied traits in 18 months of age

Estimation of variance components and heritability coefficients for studied traits in 18 month of age are shown in Table 6.

Heritability estimates were 0.65 ± 0.19, 0.37 ± 0.08, 0.48 ± 0.12, 0.32 ± 0.10, 0.73 ± 0.21 and 0.44 ± 0.11 for BW, WH, RH, BL, HG and LC, respectively.

Phenotypic and genetic correlations in 18 months of age are reported in Table 3. The genetic correlations were estimated in the range of –0.08 to 0.97. Phenotypic correlations were estimated in the range of 0.10 to 0.95. Genetic correlations between BW_{18} and body measurements traits were moderate to high and the highest genetic correlation was between BW_{18} and BL.

Table 4 Variance components for body weight (BW$_{12}$), withers height (WH$_{12}$), rump height (RH$_{12}$), body length (BL$_{12}$), heart girth (HG$_{12}$) and leg circumference (LC$_{12}$) in 12 months age

Traits	BW$_{12}$	WH$_{12}$	RH$_{12}$	BL$_{12}$	HG$_{12}$	LC$_{12}$
σ_a^2	6.70	2.06	2.16	1.70	6.92	0.36
σ_e^2	13.05	6.78	6.51	7.18	17.42	5.13
σ_p^2	19.75	8.87	8.67	8.88	24.34	5.49
h^2+SE	0.34±0.05	0.23±0.05	0.25±0.04	0.20±0.04	0.29±0.06	0.07±0.04

σ_a^2: additive genetic variance; σ_e^2: residual variance; σ_p^2: phenotypic variance and h$^2 \pm$ SE: heritability estimates and standard error.

Table 5 Phenotypic and genetic correlations among body weight (BW$_6$) with withers height (WH$_{12}$), rump height (RH$_{12}$), body length (BL$_{12}$), heart girth (HG$_{12}$) and leg circumference (LC$_{12}$) in six month age 12 months age

Traits	BW$_{12}$	WH$_{12}$	RH$_{12}$	BL$_{12}$	HG$_{12}$	LC$_{12}$
BW$_{12}$	-	0.47	0.50	0.42	0.63	0.36
WH$_{12}$	0.76	-	0.92	0.41	0.47	0.36
RH$_{12}$	0.76	0.99	-	0.44	0.49	0.35
BL$_{12}$	0.58	0.35	0.38	-	0.44	0.28
HG$_{12}$	0.95	0.74	0.72	0.59	-	0.38
LC$_{12}$	0.90	0.88	0.84	0.36	0.91	-

Table 6 Variance components for body weight (BW$_{18}$), withers height (WH$_{18}$), rump height (RH$_{18}$), body length (BL$_{18}$), heart girth (HG$_{18}$) and leg circumference (LC$_{18}$) in 18 months age

Traits	BW$_{18}$	WH$_{18}$	RH$_{18}$	BL$_{18}$	HG$_{18}$	LC$_{18}$
σ_a^2	10.69	2.17	3.02	1.63	11.52	2.08
σ_e^2	5.74	4.48	3.19	3.35	4.16	2.61
σ_p^2	16.43	7.15	6.21	4.98	15.68	4.69
h^2+SE	0.65±0.19	0.37±0.08	0.48±0.12	0.32±0.10	0.73±0.21	0.44±0.11

σ_a^2: additive genetic variance; σ_e^2: residual variance; σ_p^2: phenotypic variance and h$^2 \pm$ SE: heritability estimates and standard error.

Table 7 Phenotypic and genetic correlations among body weight (BW$_{18}$) with withers height (WH$_{18}$), rump height (RH$_{18}$), body length (BL$_{18}$), heart girth (HG$_{18}$) and leg circumference (LC$_{18}$) in six month age in 18 months age

Traits	BW$_{18}$	WH$_{18}$	RH$_{18}$	BL$_{18}$	HG$_{18}$	LC$_{18}$
BW$_{18}$	-	0.33	0.35	0.43	0.59	0.22
WH$_{18}$	0.34	-	0.95	0.36	0.35	0.23
RH$_{18}$	0.42	0.97	-	0.37	0.39	0.24
BL$_{18}$	0.81	0.16	0.33	-	0.34	0.10
HG$_{18}$	0.77	0.62	0.59	0.33	-	0.22
LC$_{18}$	0.41	0.03	-0.01	-0.08	0.30	-

Phenotypic correlations between BW$_{18}$ and body measurements traits were medium to low. These results are in agreement with reports of Mukherjee *et al.* (1986) and Singh *et al.* (1987) in brown Bengal does and grey Bengal goats, respectively.

The estimated heritability of body weight and body measurement traits in different ages showed that the values at 12 months age are less than those at 6 and 18 months age; it comes down from 6 to 12 months age, then goes up to 18 months of age. These results happened because of greater value of environmental variance at 12 months of age.

Mavrogenis *et al.* (1980) and Yazdi *et al.* (1997) reported that heritability estimates for body weight and body measurement traits increase by increasing of age, which are in disagreement with results of current study.

CONCLUSION

Body weight and body measurement are important traits in meat animals. The analyses of data on body measurement traits provide quantitative measure of body size and shape that are desirable, as they will enable genetic parameters for these traits to be estimated and also permit inclusion in bre-

eding programs. Estimation of heritability indicated that improvement in body measurements and body weight of Makuei sheep are possible through selection procedures. The positive correlation between body weight and body measurements traits in different ages indicated that selection for body measurements can lead to improve in body weight. Finally, further research need to be conducted to investigate the relationship between body weight and body measurement traits in current and other sheep breeds in different regions and ages.

ACKNOWLEDGEMENT

REFERENCES

Abbasi M.A. and Ghafouri-Kesbi F. (2011). Genetic (co)variance components for body weight and body measurements in Makooei sheep. *Asian-Australasian J. Anim. Sci.* **24,** 739-743.

Bahreini-Behzadi M.R., Shahroudi F.E. and Van vleck L.D. (2007). Estimates of genetic parameters for growth traits in Kermani sheep. *J. Anim. Breed. Genet.* **124,** 296-301.

Bathaei S.S. and Leroy P.L. (1998). Genetic and phenotypic aspects of the growth curve characteristics in Mehraban Iranian fat-tailed sheep. *Small Rumin. Res.* **29,** 261-269.

Brown J.E., Brown C.J. and Butts W.T. (1973). Evaluating relationships among immature measures of size, shape and performance of beef bulls. *J. Anim. Sci.* **36,** 1010-1020.

Cankaya S. and Kayaalp G.T. (2007). Estimation of relationship between live weights and some body measurements in German farm × hair crossbred by canonical correlation analysis. *J. Anim. Prod.* **48,** 27-32.

Hamayun Khan F.M., Ahmad R., Nawaz G. and Zubair M. (2006). Relationship of body weight with linear body measurements in goats. *J. Agric. Biol. Sci.* **3,** 51-54.

Janssens S. and Vandepitte W. (2004). Genetic parameters for body measurements and linear type traits in Belgian Blue du Maine, Suffolk and Texel sheep. *Small Rumin. Res.* **54,** 13-24.

Mavrogenis A.P., Louca A. and Robison O.W. (1980). Estimates of genetic parameters for pre-weaning and post-weaning growth traits of Chios lambs. *Anim. Prod.* **30,** 271-276.

Meyer K. (2000). DFREML Programs to Estimate Variance Components for Individual Animal Models by Restricted Maximum Likelihood (REML). Users Notes, Animal Genetics and Breeding Unit, Armidle, Australia.

Miraei-Ashtiani S.R., Seyedalian A.R. and Moradi shahrbabak M. (2007). Variance components and heritabilities for body weight traits in Sangsari sheep, using Univariate and multivariate animal models. *Small Rumin. Res.* **73,** 109-114.

Mohammadi Y., Rashidi A., Mokhtari M.S. and Beigi Nassiri M.T. (2011). The estimation of (co)variance components for growth traits and Kleiber ratios in Zandi sheep. *Small Rumin. Res.* **99,** 116-121.

Mukherjee D.K., Singh C.S.P., Mishra H.R. and Nath N. (1986). Body weight measurement relationships in brown Bengal does. *Indian J. Vet. Med.* **10,** 1004-1006.

Ravimurugan T., Thiruvenkadan A.K., Sudhakar K., Panneerselvam S. and Elango A. (2013). The estimation of body weight from body measurements in Kilakarsal sheep of Tamil Nadu, India. *Iranian J. Appl. Anim. Sci.* **3,** 357-360.

Safari E. (1986). Report for Identification of Makuie Ecotype. Published by Agriculture Ministry of Iran, Tehran, Iran.

Sahin M., Cankaya S. and Ceyhan A. (2011.) Canonical correlation analysis for estimation of relationships between some traits measured at weaning time and six-month age in Merino lambs. *Bulgarian J. Agric. Sci.* **17,** 680-686.

Salako A.E. (2006). Application of morphological indices in the Assessment of type and function in sheep. *Int. J. Morphol.* **24,** 13-18.

SAS Institute. (2011). SAS®/STAT Software, Release 9.1. SAS Institute, Inc., Cary, NC. USA.

Singh N.R., Mohanty S.C. and Mishra M. (1987). Prediction of body weight from body measurements in black Bengal goats: a note. *Indian J. Anim. Prod. Manage.* **3,** 46-49.

Snyman M.A., Erasmus G.J., Van-Wyk J.B. and Olivier J.J. (1995). Direct and maternal (co)variance components and heritability estimates for body weight at different ages and fleece traits in Afrino sheep. *Livest. Prod. Sci.* **44,** 229-235.

Supakorn C., Pralomkarn W. and Anothaisinthawee S. (2012). Estimation of genetic parameters and genetic trends for weight and body measurements at birth in sheep populations in Thailand. *Songklanakarin J. Sci. Thechnol.* **35,** 1-10.

Yazdi M.H., Engström G., Nasholm A., Johansson K., Jorjani H. and Liljedahl L.E. (1997). Genetic parameters for lamb weight at different ages and wool production in Baluchi sheep. *Anim. Sci. J.* **65,** 224-255.